spectra can be photographed, since the dispersion will also be less. The contract has not yet been filled for the Bruce telescope, since difficulty is still experienced in making charts in which the images shall be circular. Experiments are in progress in this direction, and it is hoped that the method described above as applied to the 13-inch Boyden telescope will prove equally successful with this instrument.

A variety of experiments have been made to determine the photographic magnitudes of the brighter stars on a uniform scale. It is now expected that this can be done with the transit photometer for stars brighter than the third magnitude, and that the scale can be extended to stars from the third to the sixth magnitude by a series of photographs which are being taken with a portrait lens having an aperture of 2·5 inches. The images are thrown out of focus, and the intensity of the circular discs thus obtained can be accurately measured.

ELECTRIC DISCHARGE THROUGH GASES.[1]

ONE of the most important and interesting branches of physical science is that which deals with the connection between electrical and chemical effects.

The investigations on electrolysis made within these walls by Davy and Faraday proved that the important class of electrical phenomena associated with the passage of electricity through liquids, are connected in the closest way with chemical action. They proved that no electricity will pass through most liquids unless chemical action occurs, and that for each unit of electricity which passes through the liquid there is a definite amount of chemical decomposition.

This case, though it is one where the laws are most accurately known, is but one among many electrical phenomena which are inseparable from chemical action.

So many instances of this kind have been discovered, that we may perhaps venture to hope that we are not far from the time when it will be universally recognised that many of the most fundamental questions in chemistry and electricity are but different aspects of one and the same phenomenon.

Anything which throws light on the connection between electricity and matter, interesting as it is on its own account, acquires additional interest when regarded as elucidating the connection between chemical and electrical effects, and no phenomena seem more suitable for this purpose than those which are the subject of the discourse this evening—the discharge of electricity through gases. For in gases we have matter in the state in which its properties have been most carefully studied, while the investigation of the electrical effects is facilitated by the visibility of the discharge, affording us ocular, and not merely circumstantial, evidence of what is taking place.

The points to which I wish to refer particularly this evening are, firstly, some phenomena connected with the passage of electricity from the gas to the electrode, or from the electrode to the gas; and secondly, some of the properties of the discharge when its course lies entirely in the gas.

By taking a long discharge tube, say, one fifty feet long, and observing the luminous discharge through a rotating mirror, we can trace the course of the luminosity due to a single discharge, say, one due to once breaking the primary circuit of an induction coil; if we do so, we find that the luminosity follows the direction of the positive current through the tube. That is, the luminosity begins at the positive electrode, it then rushes down the tube with enormous velocity, but when it gets to the negative electrode, it receives a check; it does not disappear at once in that electrode like a rabbit going down a hole, but lingers around the electrode some time before entering it. In consequence of this delay in the positive discharge in getting out of the gas, there is an accumulation of positive electricity in the neighbourhood of the negative electrode until the potential fall at this electrode increases to about 200 or 300 volts.

The positive electricity which accompanies the discharge thus finds considerable difficulty in getting from the gas to the metal, though, as I hope to show you later on, as long as it keeps in the gas, it meets with what we may, in consideration of the views sometimes enunciated on this subject, call a ridiculously small amount of resistance, its real difficulty is to get out of the gas.

Though this effect has long been known, it is so important that I will venture to show one or two experiments which illustrate it. The arrangement of the first experiment is shown in Fig. 1. The apparatus consists of a main discharge tube, across which is fastened a diaphragm made of excessively thin platinum leaf; there is a side passage from the tube, leading from one side of the diaphragm to the other, this is connected to a barometer tube, and by raising the cistern containing the mercury I can stop up the passage by a pellet of mercury. We will first observe the discharge when the side passage is open; you see that the discharge, instead of passing across the thin piece of platinum leaf, takes the very much longer route round the side tube, so as to avoid crossing the metal. We will now raise the mercury cistern, and close the side tube by a pellet of mercury; the discharge now has no alternative but to cross the metal at some part of its course, and you see that the main portion of the discharge goes back into the main tube.

Fig. 1.

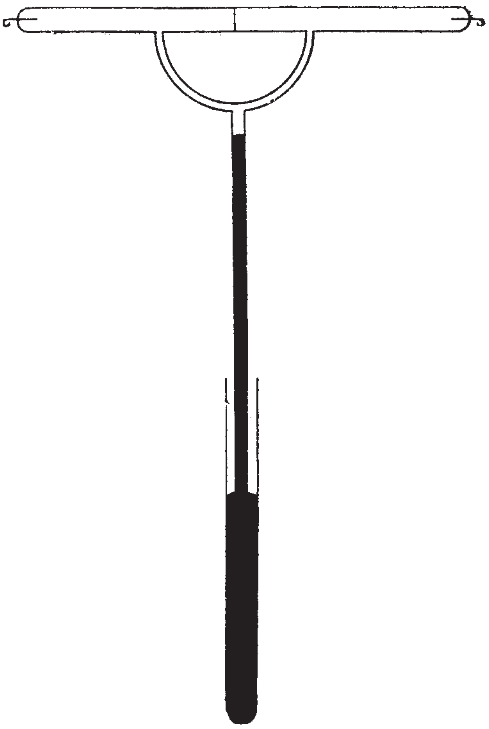
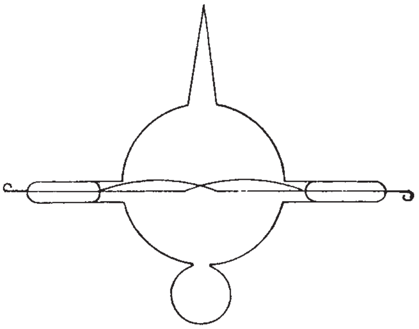


Fig. 2.



In the second experiment the metal diaphragm is replaced by a very thin plate of mica; when the side passage is opened the discharge goes round, but when this is closed by a pellet of mercury the discharge prefers to go across the mica than through the mercury.

---

[1] Lecture delivered at the Royal Institution by Prof. J. J. Thomson, F.R.S.

A second experiment which shows the same thing is the following. Two long electrodes are fused into a bulb, so that the tip of an electrode is a considerable distance from the place where it passes through the glass. We will now send an alternating discharge through the tube, and you will see, I think, that the discharge, instead of going straight across the short distance between the ends of the electrodes, goes from the tip of one electrode to the place where the other passes through the glass, thus staying as long as possible in the gas before passing into the metal. The appearance of the discharge shows that the positive electrode is at the end of the wire, the negative at the junction of the wire with the glass.

Another interesting example of the difficulty the discharge experiences in passing from gas to metal is the discovery made by Profs. Liveing and Dewar, that when the discharge passes through a gas containing a large quantity of metallic dust, the light from the discharge, when examined in the spectroscope, does not show any of the lines of the metal.

The difficulty which the positive electricity finds in passing from the gas to the electrode depends a great deal upon the nature of the gas, as well as upon that of the electrode; it is influenced by the position of the gas and the electrode relatively to one another in the electro-chemical series.

I have lately made a series of experiments on this point in the following way. An alternating discharge from a high tension transformer was made to pass between two electrodes fused into a bulb, which could be filled with the gases under examination. Another electrode connected to an electrometer, passed into the bulb, and was arranged so that it could be moved about from one part of it to the other. When the electrodes were metal and the bulb was filled with the electronegative gas oxygen, the electrode received a positive charge in whatever part of the bulb it was situated; if now the bulb was filled with hydrogen at atmospheric pressure, then in the regions remote from the arc the electrode received a positive charge, but in the immediate neighbourhood of the arc itself it received a negative charge. When the pressure was reduced the region in which the charge was negative contracted, and finally at pressures about one-third of an atmosphere, seemed to disappear, and the electrode got a slight positive charge in whatever position it was placed. If now, instead of using metallic electrodes we use well-oxidised copper ones, and repeat the experiment in hydrogen, working at a pressure when there was only positive electricity, when the electrodes were bright and polished, we find that with the oxidised electrodes every particle of positive electricity is taken out of the tube, and a negative charge is left. This negative charge remains until the copper oxide is completely reduced; when this occurs the negative charge disappears, and is replaced by positive. Thus, under the same conditions as to the nature of the gas and the pressure, the bright copper electrodes leave a positive charge in the gas, while the oxidised ones leave a negative charge.

The most probable explanation of these results seems to me to be the view that the communication of electricity from gas to the electrode, or from the electrode to gas, is facilitated by the temporary formation of something of the nature of a chemical compound between the gas and the metal. In all such compounds the metal is the electro-positive element, and has the positive charge, the gas being the electro-negative and carrying the negative charge. Now consider the case when the negative charge is on the gas, and the positive charge on the metal; then the gas and metal have got the charges proper to them in any compound they may form, and are thus in a fit state to combine, or according to this view, allow the negative electricity to pass from the gas to the copper. But, now, suppose the gas was positively electrified, the gas and the metal have now opposite charges to those proper to them in a compound, and before the union of gas and metal in this state could result in anything but a most unstable compound, an additional process must be gone through —*i.e.* the charges on the gas and metal must be interchanged. Thus the conditions for the combination of the gas and metal are more complex when the gas is positively electrified than when it is negatively electrified, and thus, on the view that the communication of electricity between the gas and the metal involves a sort of chemical combination, we see that the negative electricity will escape more easily from the gas to the metal than the positive. Now consider the case when the gas was hydrogen, the electrodes oxidised copper; the hydrogen combines now not with the metal, but with the oxygen, forming water, in which hydrogen is the electro-positive element; thus, in this case, it is the positively charged hydrogen which is in the state best fitted for pairing. The consequence is, the positive charge would be most readily removed from the gas and the negative left—exactly the opposite to that which occurred when the electrodes were bright. This reversal, as I stated before, is verified by experiment.

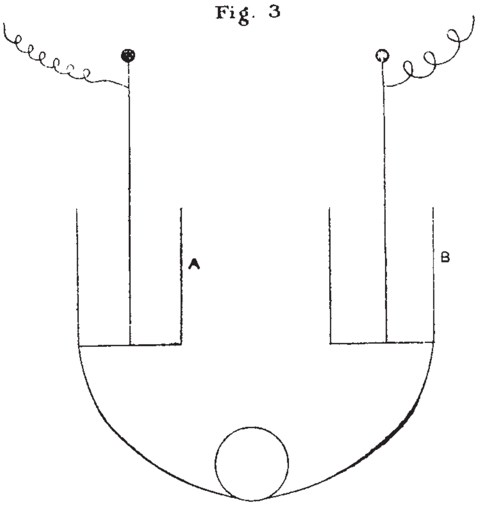
I have hitherto only spoken of the phenomena which accompany the passage of electricity from the electrode to the gas, or from the gas to the electrode.

I shall now pass on to consider the properties of the discharge when it is entirely confined to the gas.

We may produce a discharge which, during the whole of its course, shall be confined to the gas in the way represented in the diagram.

The two poles of a Wimshurst machine are connected to the insides of two jars A and B, while the outsides of these jars are connected together by a metal wire wound so as to form a coil. The electricity from the Wimshurst machine charges up the jars, the difference of potential between the poles increases until a spark passes. The passage of the spark puts the insides of the two jars in connection, and the jars are discharged. The discharge of the jar, as was proved from the theory of electromagnet action by Lord Kelvin more than forty years ago, and shortly afterwards confirmed by the experiments of Feddersen, is an oscillatory one, producing currents surging backwards and forwards through the wires with extraordinary rapidity. The subject of these oscillatory currents is one which is tinged with melancholy. In the beginning of 1894 we lost Hertz, whose splendid work on these electrical oscillations is known to you all. The Managers of this Institution have marked their sense of the importance of this work by devoting a special lecture to this work alone, and they have entrusted that lecture to a most distinguished worker in the same field as Hertz. It would therefore be presumptuous on my part to refer in any detail to Hertz's work; but no physicist, and least of all one who is a member of Maxwell's University, could pass over in silence the death of Hertz.

Fig. 3



When Hertz began his magnificent experiments on electric oscillations, there were many theories of electrical action. When he had finished them there was only one, Clerk Maxwell's.

Hertz's work was done with very much quicker vibrations than those produced by the apparatus now on the screen; this, however, gives rise to currents through the coil changing their direction some million times a second. If we place in the coil an exhausted bulb, the bulb in reality will be the secondary of an induction coil, and will be exposed to electromotive forces tending to produce circular currents parallel to the plane of the coil.

I will now place a bulb inside this coil, and you see that a circular ring discharge passes through it, and this discharge passes entirely in the gas.

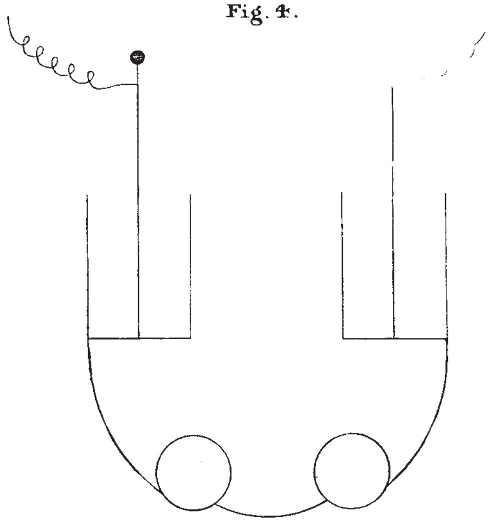
The gas in the bulb now in the coil is the vapour of silicon tetrachloride; it happens to be the bulb which gives a brighter ring than any others I possess.

If this ring discharge passes through air at different pressures, the colour of the discharge changes very considerably. The first bulb I put in was at fairly high pressure, about $\frac{1}{10}$ of a millimetre or so. I will now put in another at a lower pressure, and then one at a still lower pressure. Mr. Newall, who has been working at the spectra of these discharges, finds that at the pressure in the first bulb the spectrum is due to nitrogen ; at the second stage it is due to mercury vapour ; the bulb was pumped by a mercury pump, so that there is in the bulb a certain quantity of mercury vapour.

The apple-green colour in the more highly exhausted bulb is due to some compound of sulphur, which has got into the bulb from the sulphuric acid used to dry the gas. Mr. Newall finds that if the ordinary discharge from a coil between electrodes is taken in such a bulb, there is no trace of this sulphur spectrum. He has also found that when the bulb is at a pressure intermediate between what I may call the mercury and the sulphur stage, when the mercury and sulphur lines are both visible, these sets of lines come from different layers, the sulphur lines coming from a layer nearer the surface than the other.

If we take the discharge through a bulb containing oxygen, you will see that the ring discharge is succeeded by a bright glow ; at first the colour is somewhat opaque, but gradually gets more transparent and changes colour. This gives a continuous spectrum crossed by a few bright lines. If we take the discharge through cyanogen, you see that the glow is even more persistent than the oxygen, though it is not so bright ; all the gases which show this glow belong to the class of substances which polymerise—that is, whose molecules can combine with each other. I imagine that what takes place in bulbs filled with these substances is that the discharge produces a polymeric modification, and that this gradually returns to its original state, and while doing so gives out a phosphorescent light. It is in accordance with this that at a high temperature where ozone cannot exist a discharge through an oxygen bulb does not show any glow.

Fig. 4.



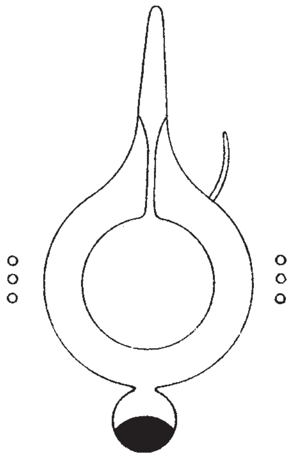
I said at the beginning of this discourse that gases were exceedingly good conductors of electricity. I will now endeavour to show an experiment which proves that statement. The apparatus which I shall use for this purpose is a slight modification of the one I have used for producing the ring discharge ; the only difference is that in the wire connecting the two coatings of the jars there are two loops instead of one. In one of these loops an exhausted bulb is placed to serve as a kind of galvanometer ; the brightness of the discharge is an indication of the strength of the current flowing round the coil. If I place a second conductor in the other loop, currents will be started in it, and part of the energy of the discharge will be absorbed ; this will leave less energy available for the bulb in the first, so that the discharge in this bulb will be dimmer. The effect produced on the discharge will depend upon the conductivity of the substance placed in the second loop.

The effect is not directly proportional to the conductivity ; in fact, a perfect conductor would not produce any diminution, nor would an absolute non-conductor ; for a given period, and with apparatus of given dimensions, there is a certain conductivity which gives a maximum effect ; this follows easily from the theory of induction of currents, but at this late period in the evening I will take a shorter course and prove it by an experiment.

I put a piece of brass in this loop, and you see it produces but a small effect upon the brightness of the discharge. Instead of brass I now insert a plumbago crucible, which, though a conductor, is not nearly so good a one as the brass, and you see the discharge in the indicating bulb is completely stopped.

I will now place in the second loop an exhausted bulb ; you see it produces a decided diminution in the intensity of the discharge in the galvanometer bulb. I now replace the bulb by another of the same size containing dilute sulphuric acid ; you see it does not produce nearly so large an effect as the exhausted bulb ; this might be due, as we have seen, to the sulphuric acid being either too good or too bad a conductor. I can show that it is the latter by putting a bulb in filled with a stronger solution, which has a higher conductivity than the weak solution ; if the smallness of the effect produced by the weak acid were due to its being a better conductor than the gas, then increasing the conductivity would still further diminish the effect of the acid ; you see, on the contrary, that the strong acid produces a distinctly greater effect than the weak, hence the rarefied gas in the bulb is a better conductor even than the strong electrolyte. Let us consider for a moment the molecular conductivities of the two substances, the rarefied gas and the electrolyte. The pressure of the gas is about $\frac{1}{100}$ of a millimetre, while in the electrolyte there are sufficient molecules of the acid to produce, if they were in the gaseous state, a pressure of more than 100 atmospheres ; thus the conductivity of the gas estimated per molecule is about 10 million times that of the acid, this is greater than the molecular conductivity of even the best conducting metals.

Fig. 5.



If the pressure of the gas is diminished below a certain point, the conductivity begins to diminish. I have here an experiment which I hope will show this. The apparatus (Fig. 5) consists of two bulbs, one outside the other ; the inner bulb contains air at a low pressure, while the space between the two bulbs is a very high vacuum containing practically nothing but a little mercury and its vapour. The amount of mercury vapour in this space is, at the temperature of the room, exceedingly small, but as the apparatus is heated the vapour pressure increases, and we are thus able to produce a fairly wide range of pressure in the space between the bulbs. The outer sphere is surrounded by the coil connecting the outer coatings of the two Leyden jars. When the space between the bulbs is a conductor, the alternating currents circulating in the coil will induce in this conductor currents whose inductive effect is opposite to that of the currents in the coil ; and in this case this layer will screen off from the inner bulb the electromotive force due to the alternating currents in the coil. If, on the other hand, the space between the bulbs is a non-conductor, the inner bulb will be exposed to the full effect of these forces. We now try the experiment: you observe that when the mercury is cold, and consequently the pressure in the space between the bulbs very low, a bright discharge passes through the inner bulb, while the space between the bulbs remains quite dark; when we heat the mercury so as to increase the pressure of its vapour, a bright discharge passes through the outer layer, while the inner bulb is quite dark; the outer layer is now a conductor, and by its action screens off from the inner bulb the induction of the coil.

The last experiment I have to show is one on the effect produced by a magnetic field on the discharge. When the discharge has to flow across the lines of magnetic force, the pressure of the magnetic field retards the discharge; when, however, the discharge flows along the lines of magnetic force, the discharge is helped by the magnetic field. This is shown in the following experiment. A is a bulb; B a square tube, one side of which is placed between the poles of an electromagnet; the coil C, which connects the outside coatings of the jars, can be adjusted so that when the magnet is "off," the discharge passes through the bulb but not round the square tube; when, however, the magnet is "on," the discharge passes in the square tube but not in the bulb. In the square tube the discharge passes along the lines of magnetic force and is helped; in the bulb it passes across them and is retarded.

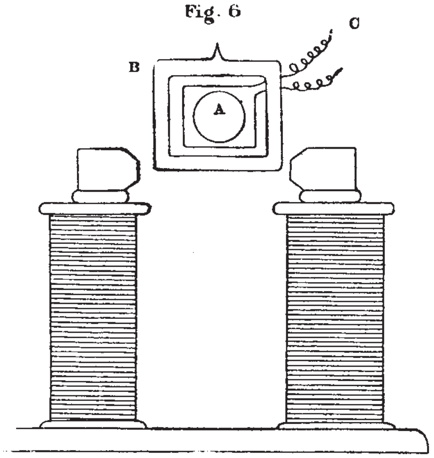


Fig. 6

UNIVERSITY AND EDUCATIONAL INTELLIGENCE.

OXFORD.—In a Convocation held on Tuesday, January 29, the degree of Doctor of Medicine, by decree of the House, was conferred on J. S. Burdon Sanderson, F.R.S., Regius Professor of Medicine. Prof. Sanderson was at the same time empowered to discharge the duties of the Waynflete Professor of Physiology, and to dispose of the income of the department during the vacancy in the Waynflete Professorship.

The amendments to the proposed form of statute on degrees for research will be submitted to Congregation on Tuesday, February 12. There are no less than sixty-three amendments, most of which are consequential. The chief amendments propose that the degree of Bachelor of Arts shall be substituted for the proposed degrees of Bachelor of Letters and Bachelor of Science; that the delegacy for the supervision of candidates shall be chosen from among a limited number of University officials, and that there shall be no such delegacy, but that the supervision shall be entrusted to the Boards of Studies.

The Sibthorpian Professor of Rural Economy will deliver an inaugural lecture on Monday, February 4, at 5.30 p.m., on "The Present Relations of Agricultural Art and Natural Science."

Mr. A. B. Trevor Battye will give a lecture before the Ashmolean Society on Monday, February 4, at 8.30 p.m., on his experiences in Kolguev Island.

The Vice-Chancellor has received for the University a bequest from the late Miss Susan Kidd of a portrait of her father, Dr. John Kidd, of Christ Church, formerly Regius Professor of Medicine.

CAMBRIDGE.—The Special Board for Biology and Geology propose that in future the Walsingham Medal, given by the Lord High Steward annually for biological research, shall be open to graduates of the University up to the standing of Master of Arts. Of the three Medals offered, two have been awarded—one for a zoological and the other for a botanical essay. It is also proposed that the Medal shall not be awarded twice to the same person.

The funeral of the late Prof. Cayley will take place on Friday, February 1, in Trinity College Chapel, and the Mill Road Cemetery. Members of the University desiring to be present, are requested to assemble in the College Hall at 1.45 p.m.

The Sedgwick Memorial Syndicate have been empowered to reconsider the plans, or prepare new ones, for the Geological Museum. The estimates for Mr. Jackson's plan exceeded the means at the disposal of the University.

Dr. L. E. Shore, St. John's College, has been appointed an additional member of the Medical Board. Dr. A. Ransome, F.R.S., Dr. J. L. Notter, Dr. T. Stevenson, F.R.S., and Dr. R. Thorne Thorne, C.B., F.R.S., have been appointed Examiners in State Medicine for the current year.

At the Matriculation on January 28, seventeen new students were entered. This brings the total for the present academical year up to 894.

THE Executive Committee of the City and Guilds of London Institute have awarded the first Salters' Company Research Fellowship for the encouragement of higher research in chemistry in its relation to manufactures, to Dr. Martin O. Foster. Dr. M. O. Foster is an old student of the City and Guilds Technical College, Finsbury, and Doctor of Philosophy of the University of Würzburg. For several months he has been engaged in investigating some new derivatives of camphor in the Research Laboratory of the City and Guilds Central Technical College and by the aid of the Salters' Company's Research Fellowship, he proposes to pursue this line of work.

THE Organised Science Schools of the Department of Science and Art are schools in which the instruction is carried on methodically according to one or other of the courses laid down by the Department, or which has been specially submitted to and approved by it. It can easily be understood that such schools represent a very important stage in the system of scientific education which Mr. Acland is doing so much to improve. A number of new regulations, relating to these schools, have just been issued, to come into force after the examinations next May. The most important feature of the new scheme is the introduction of payment on inspection instead of payment on results, for by far the larger part of the instruction given in organised science schools. This modification, which applies to 120 science schools in the United Kingdom, has only become possible since the appointment of a staff of Science and Art inspectors. Another noteworthy feature is that reasonable latitude will be allowed to the teacher as to the nature of the course he may pursue provided the instruction is sound, satisfactory in amount, and combined with proper practical work. Even more satisfactory are the instructions that the practical chemistry for the first year's course should include the setting up of apparatus—weighing and other chemical manipulations, the preparation of gases, the estimation of volume, and so on. Analysis will, in future, occupy a secondary position in introductory courses. The mechanical test-tubing, which has hitherto formed the greater part of practical chemistry in Departmental schools, will thus give place to practical work of real educational value. We also observe that provision is made for a certain amount of literary instruction being given whilst the student is pursuing his science curriculum; that a choice of advanced courses is given; and that an alternative programme suitable for women is formulated, and instruction in subjects specially adapted to them is demanded; that practical instruction must be given in the subjects of science simultaneously with the theoretical instruction. Clearly, the new rules will greatly assist the development and better organisation of scientific education.

SCIENTIFIC SERIALS.

American Journal of Science, January.—Late glacial or Champlain subsidence and reëlevation of the St. Lawrence River basin, by Warren Upham. From the Champlain submergence the Atlantic coast of North America was raised somewhat higher than now; and its latest movement from New Jersey to Greenland has been a moderate depression. As in Scandinavia,